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Newsletter Report: Large Freestanding GaN Substrates by Hydride Vapor Phase Epitaxy Using GaAs as a Starting Substrate

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Contents:

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1. Summary

A freestanding GaN substrate (>2 inches in size) was successfully prepared for the first time by hydride vapor phase epitaxy (HVPE) using GaAs as a starting substrate. In the experiment, a GaAs (III)A substrate with a SiO_2 mask pattern on its surface was used. A thick GaN layer was grown on the GaAs substrate at 1030°C through the openings in the SiO_2 mask. By dissolving the GaAs substrate in aqua regia, a freestanding GaN substrate (about 500 µm thick) was obtained. The full-width at half maximum (FWHM) in the ω-mode X-ray diffraction (XRD) profile of GaN (0002) plane was 106 arcsec. The dislocation density of the GaN substrate obtained was determined to be as low as 2×10^5 cm $^{-2}$ by plane-view transmission electron microscopy (TEM). Hall measurements revealed the n-type conductivity of the GaN substrate with typical carrier concentration and carrier mobility of 5×10^{18} cm $^{-3}$ and l70cm^2.V^{-1}.s^{-1}, respectively.

2. Discussion

GaN-based compound semiconductors are one of the most attractive wide-band-gap materials for short-wavelength light-emitting devices and for high-temperature electronic devices. Improvements in the crystalline quality of GaN-based semiconductors over the past ten years have made it possible to fabricate high luminescent blue/green light emitting diodes (LEDs) and violet laser diodes (LDS). Due to the lack of GaN substrates, these devices must be grown on foreign substrates such as sapphire or SiC, causing dislocations and cracking of the grown layer (due to lattice mismatch and differences in the thermal expansion coefficient between GaN and the substrate). Currently, a high quality freestanding GaN substrate is desperately needed for further improvements in the lifetime and fabrication process of LDs. If a large freestanding GaN substrate is obtained, the science and technology of group **III** nitrides will be drastically changed.

There have been several attempts to prepare bulk GaN crystals such as solution growth under ultrahigh nitrogen pressure or sublimation. However, the size of GaN crystals obtained in these methods is too small for practical use. The current largest freestanding GaN substrate is obtained by growing a thick GaN layer on a sapphire substrate using hydride vapor phase epitaxy (HVPE) and separating the grown layer from the sapphire substrate. Epitaxial lateral overgrowth (ELO) of GaN on a patterned mask has also been extensively studied to reduce the dislocation density in the grown layer. However, it is neither very easy nor productive to separate the GaN layer from the sapphire substrate because sapphire is very hard and is not etched by any etchant.

If a high quality, thick GaN layer can be grown on a GaAs substrate, it is very attractive since the GaAs substrate can be easily removed by aqua regia. No reports have appeared on the preparation of a freestanding GaN substrate using GaAs as a starting substrate. After the earliest report that the GaN low temperature buffer layer could be grown even in the halide system, the growth of high quality GaN layers on GaAs substrates by metalorganic hydrogen chloride vapor phase epitaxy (MOHVPE) was extensively studied in which the reaction for GaN deposition is the same as that in conventional HVPE. Suitable conditions for the HVPE growth of GaN were also studied by thermodynamic analysis. These studies revealed that the GaAs substrate covered with a 50-nm-thick low-temperature-deposited GaN buffer layer did not deteriorate even after subsequent heating to 1000°C (when a GaAs (III)A substrate was used). Additionally, a thick GaN layer with a mirror-like surface could be grown on the GaAs substrate at a temperature of 1000°C or above. Therefore, an attempt has been made to fabricate a freestanding GaN substrate using GaAs (I I 1)A as a starting substrate.

3. Points of Contact

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